The GLAST Burst Monitor

Charles Meegan*, Narayana Bhat¶, Valerie Connaughton¶, Michael Briggs¶, Roland Diehl§, Gerald Fishman*, Jochen Greiner§, R. Marc Kippen†, Andreas von Kienlin§, Chryssa Kouveliotou*, Giselher Lichti§, William Paciesas¶, Robert Preece¶, Helmut Steinle§, and Colleen Wilson-Hodge*

**Marshall Space Flight Center, VP62, Huntsville, AL 35812 USA*
¶University of Alabama, NSSTC, 320 Sparkman Drive, Huntsville, AL 35805 USA
§Max-Planck-Institute for Extraterrestrial Physics,Giessenbachstrass,e 85748 Garching, Germany
†Los Alamos National Laboratory, ISR-1, MS B244, Los Alamos, NM 87545 USA

Abstract. The GLAST Burst Monitor (GBM) comprises an array of NaI and BGO scintillation detectors designed to enhance the scientific return from GLAST in the study of gamma-ray bursts (GRBs). By observing in the 10 keV to 30 MeV energy range, GBM extends the spectral coverage of GRBs more than 3 decades below the LAT energy threshold. GBM computes burst locations on-board, allowing repointing of the GLAST Observatory to place strong bursts within the LAT field-of-view to observe delayed high-energy emission.

Keywords: Gamma-ray bursts, Instrumentation.
PACS: 95.55.Ka

INTRODUCTION

The Large Area Telescope (LAT) on the GLAST Observatory will make observations of high-energy emission (>20 MeV) from GRBs with unprecedented sensitivity. This energy range has been largely unexplored, although some tantalizing observations from EGRET on the Compton Gamma Ray Observatory showed delayed high-energy emission [1] [2]. The purpose of the GLAST Burst Monitor (GBM) is to extend the energy range of GRB observations from the LAT threshold down to the range covered by previous burst instruments. This capability will tie the new observations to the large existing GRB database and illuminate the energy-dependent changes in the temporal structure. GRB spectra are usually characterized by three parameters[3]: the low-energy slope α, a break energy E_b, and a high-energy slope β. Since E_b always lies below the LAT energy threshold (as far as we know), GBM observations are necessary to measure α and E_b, and thereby determine the total burst fluence.

Another contribution of GBM is detection and localization of bursts over a wider field-of-view than the LAT. This will allow the observatory to be repointed to particularly interesting bursts, enabling LAT observations of delayed high-energy emissions. We currently plan to perform such repointings only for the one or two strongest bursts each year.

FLIGHT HARDWARE

GBM comprises 12 Sodium Iodide (NaI) scintillation detectors, 2 Bismuth Germanate (BGO) detectors, a Data Processing Unit (DPU), and a Power Supply Box (PSB). The NaI detectors are ½ inch thick by 5 inch in diameter, with a thin Beryllium entrance window, coupled to a 5 inch photomultiplier tube (PMT). They cover the energy range of ~8 keV to 1 MeV and are used to determine GRB localizations. The BGO detectors are 5 inch thick by 5 inch diameter, viewed by two PMTs. They cover the 150 keV to ~30 MeV energy range, providing overlap with both the NaI detectors and the LAT. The detectors are oriented and positioned on the spacecraft so as to provide

approximately uniform coverage of the unocculted sky. Bursts will typically illuminate three or more of the NaI detectors and one of the BGO detectors.

The DPU processes the detector inputs, constructs pulse height histograms, formats data for output, and processes instrument commands. It provides the interface to the spacecraft for science and housekeeping data.

The PSB generates regulated voltage for the DPU and the detectors, as well as the high voltage for the detector photomultipliers.

Figure 1 is a block diagram of the instrument showing the interconnections among the hardware components.

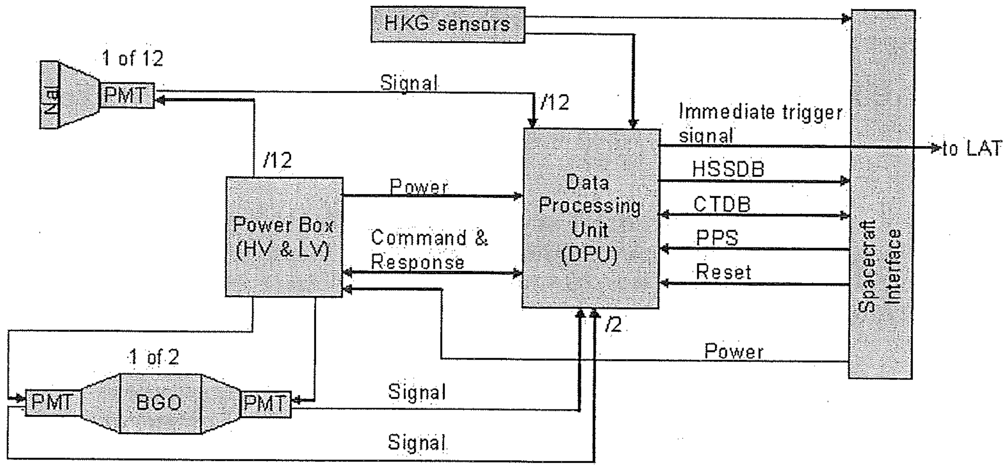


Figure 1. Block diagram of GBM flight hardware.

DATA TYPES

GBM normally produces two types of data, called CTIME and CSPEC. These are histograms of spectra from each detector, with different temporal and spectral resolution. Time-tagged event (TTE) data are transmitted when a burst occurs. These data encode the time of arrival and energy of each photon event in each detector. A ring buffer of 500,000 TTE events is frozen at the time of a trigger and later transmitted. These data types are summarized in Table 1.

When a burst occurs, additional data (referred to as TRIGDAT) are generated and transmitted to the ground in near-real time to facilitate ground-based follow-up observations. TRIGDAT data are also used by the Burst Alert Processor (BAP) to autonomously compute and disseminate burst locations to higher accuracy than can be achieved on-board.

TABLE 1. Data Types.

Name	Purpose	Temporal Resolution	Energy Resolution
CSPEC	Continuous high spectral resolution	Nominal: 8.192 seconds During Bursts: 1.024 seconds Adjustable Range: 1.024 – 32.768 s	128 energy channels (adjustable channel boundaries)
CTIME	Continuous high time resolution	Nominal: 0.256 seconds During Bursts: 0.064 seconds Adjustable Range: 0.064 – 1.024 s	8 energy channels (adjustable channel boundaries)
TTE	Time-tagged events during bursts	2 microsecond time tags for 300 s after trigger; 500K events before trigger. Max. rate, all detectors: 375 kHz.	128 energy channels (adjustable channel boundaries)

BURST TRIGGERS

GBM flight software will implement an on-board burst trigger that will initiate an increase in data transmission. A trigger occurs if the count rates in two or more of the NaI detectors exceed a specified statistical significance

above the background rate. The required significance is separately adjustable for five different time scales (16 ms, 64 ms, 256 ms, 1.024 s, and 4.096 s) in up to five adjustable energy ranges. The nominal trigger, which will always be enabled, uses the 1.024 s time scale and the 50-300 keV energy band. The nominal significance threshold is 4.5 σ.

When a burst trigger occurs, GBM begins transmitting time-tagged event data for 300 seconds. A ring buffer of 500,000 pre-trigger time-tagged events is also transmitted. On-board software also computes the direction to the event, the classification likelihood (GRB, solar flare, particle precipitation, etc.), and peak flux and fluence estimates. These parameters are sent to the LAT and to the ground in near-real time. Trigger information will be distributed to ground-based observers via the GCN. The predicted rate of GRB triggers is 200 per year.

Trigger events are localized on-board by comparing the relative count rates of the NaI detectors to a table of predicted rates corresponding to 1634 directions (in spacecraft coordinates).

Trigger events are categorized on-board by computing the Bayesian probability for several classes of events, including GRB, SGR, solar flare, or particle precipitation. Parameters considered are the event localization, spectral hardness, and the geomagnetic latitude of observatory.

SUMMARY

GBM will enhance the scientific return from GLAST in the study of GRBs by extending the energy range down to ~8 keV and by providing real-time burst locations over the entire unocculted sky. Table 2 lists the expected values for several key parameters of the instrument. More about the GBM and its performance can be found in Lichti et al. [4] and references therein.

The primary science investigations that the GBM team will conduct will be computing and disseminating burst locations, generating a catalog of GBM-triggered bursts, and, in collaboration with LAT team members, performing joint spectral fits of GRBs that are observed by both LAT and GBM. The production of continuous background data as well as triggers on other types of transient events enable several other projects that are appropriate for Guest Investigations. These include studies of solar flares, long period X-ray pulsars, SGRs, and transient hard X-ray sources.

TABLE 2. GBM Performance.

Parameter	Expected Performance
Energy Range	~8 keV to 30 MeV
Energy Resolution	~14% at 100 keV; ~9% at 1MeV
Dead time per event	2.6 microseconds
High Rate Performance	< 2 % distortion at 50,000 counts/s
On-board Trigger Threshold	0.7 photons cm^{-2} s^{-1}
On-board Burst Location Error	< 15 °
Burst Trigger Rate	~200 per year

ACKNOWLEDGEMENTS

The GBM science team appreciates the excellent engineering support provided by our home institutions and our contractors. Crismatec manufactured the crystal assemblies. Jena-Optronic GmbH produced the detector electronics and integrated and tested the detector assemblies. EADS Astrium designed, built and tested the Power Box. Southwest Research Institute designed, built, and tested the DPU. The German part of the GBM project was supported by the BMBF via the DLR under the contract number 50 QV 0301.

REFERENCES

1. K. Hurley, *Nature,* **372,** 652 (1994) .
2. M. M. Gonzales, B. L. Dingus, Y. Kaneko, R. D. Preece, C. D. Dermer, and M. S. Briggs, *Nature.,* **424**, 749 (2003).
3. D. Band, J. Matteson, L. Ford, B. Schaefer, D. Palmer, B. Teegarden, T. Cline, M. Briggs, W. Paciesas, G. Pendleton, G. Fishman, C. Kouveliotou, et al., *Astrophys. J.,* **413**, 281 (1993).
4. G. Lichti, et al.., "The State of the GBM Project 1½ Years Before Launch" in *Gamma-Ray Bursts: Prospects for GLAST*, edited by M Axelsson and F. Ryde., AIP Conference Proceedings 906, American Institute of Physics, New York, 2007.

MSFC-565

The GLAST Burst Monitor

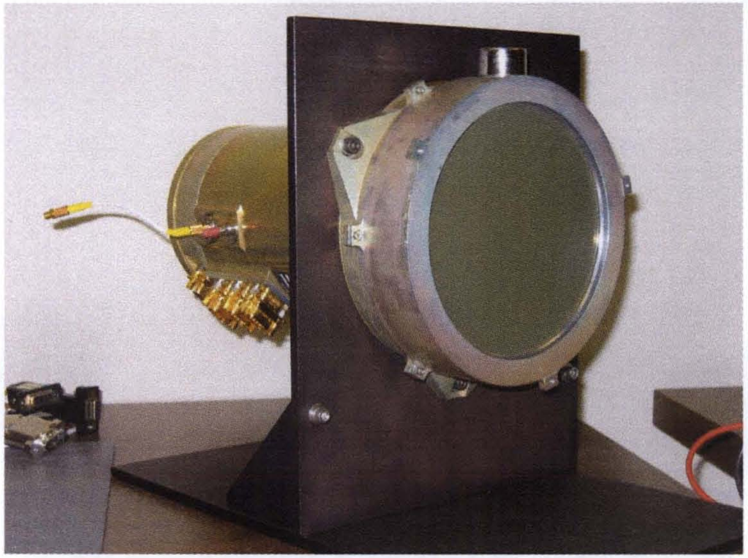
Charles Meegan[1], Narayana Bhat[2], Valerie Connaughton[2], Michael Briggs[2], Roland Diehl[3], Gerald Fishman[1], Jochen Greiner[3], R. Marc Kippen[4], Andreas von Kienlin[3], Chryssa Kouveliotou[1], Giselher Lichti[3], William Paciesas[2], Robert Preece[2], Helmut Steinle[3], Colleen Wilson-Hodge[1]

(1) NASA/Marshall Space flight Center
(2) University of Alabama, Huntsville
(3) Max Planck Institute for Extraterrestrial Physics, Garching, Germany
(4) Los Alamos National Laboratory

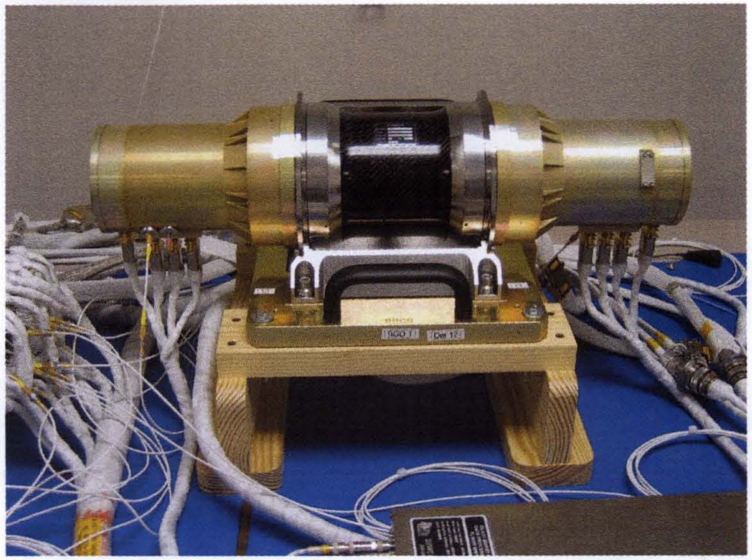
Overview

The Gamma Ray Large Area Space Telescope (GLAST) observatory, scheduled for launch in the spring of 2008, comprises the Large Area Telescope (LAT) and the GLAST Burst Monitor (GBM). The Burst Monitor will enhance gamma-ray burst observations of the main telescope by extending spectral coverage downward into the range of spectral breaks studied in detail by current databases. Furthermore, it will provide a trigger for re-orienting the spacecraft to observe delayed emission from bursts outside the LAT field of view. GBM consists of twelve NaI and two BGO scintillation detectors operating in the 10 keV to 30 MeV range and covering the entire unocculted sky.

Detectors

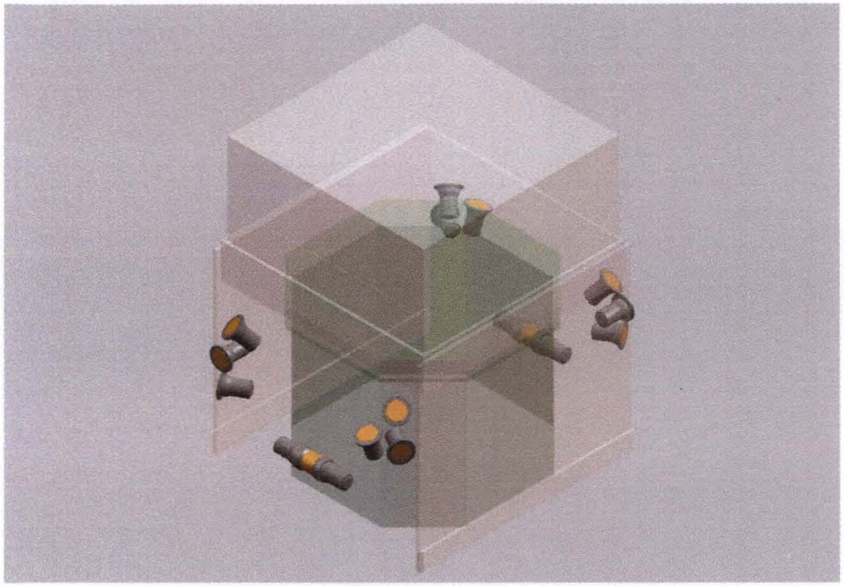


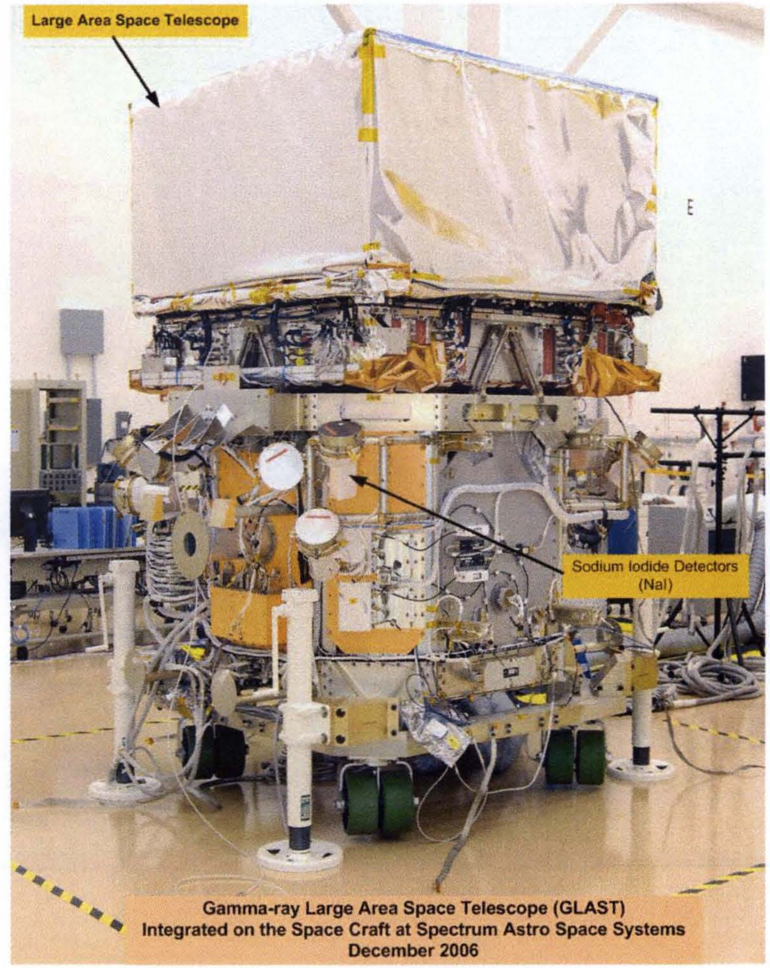
Twelve sodium iodide (NaI) detectors cover the energy range of 10 keV to 1 MeV. They are 5" in diameter and 0.5" in thickness, with a Beryllium entrance window. In addition to covering the low energy range for burst spectra, the NaI detectors are used to obtain burst locations.



Two bismuth germanate (BGO) detectors cover the energy range of 150 keV to 30 MeV, overlapping the NaI energy range and extend to the lower limit of the LAT energy range. The BGO detectors are 5" in diameter and 5" in thickness and viewed by two photomultiplier tubes for better light collection and for redundancy.

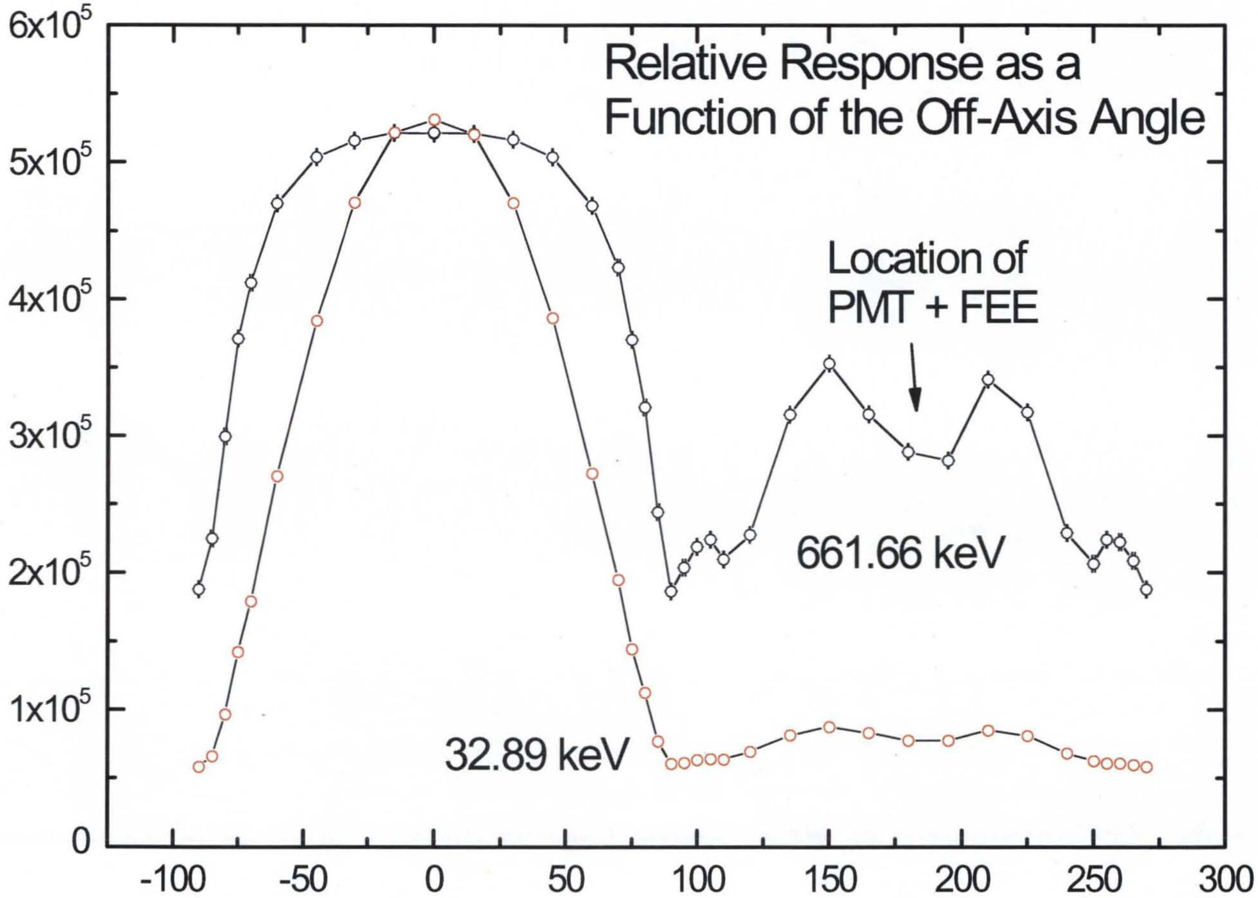
Detector Placement



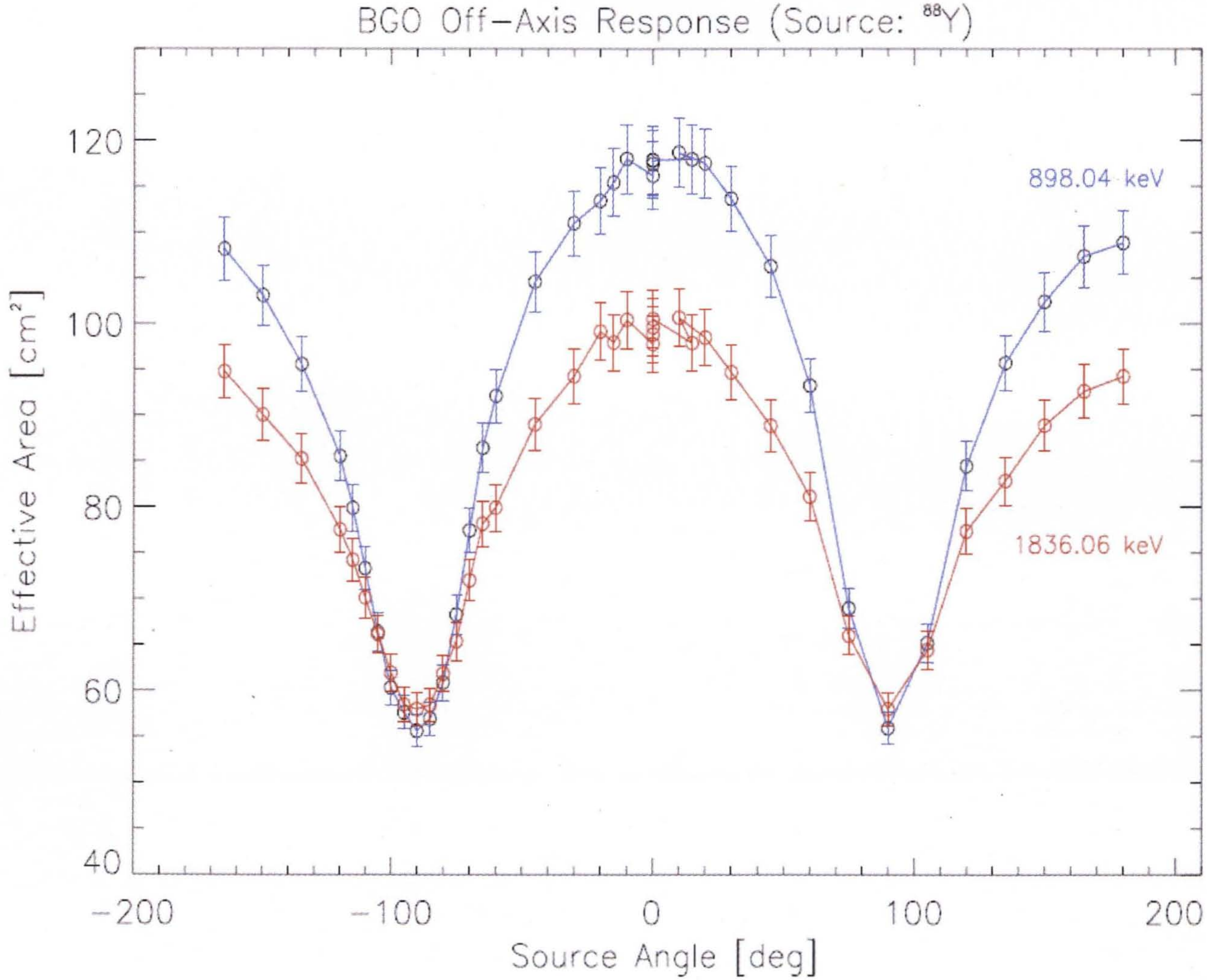


The GBM detectors are positioned on two sides of the spacecraft such that any burst above the horizon will illuminate at least three NaI detectors and one BGO detector.

NaI Detector Angular Response



BGO Detector Angular Response



Burst Trigger

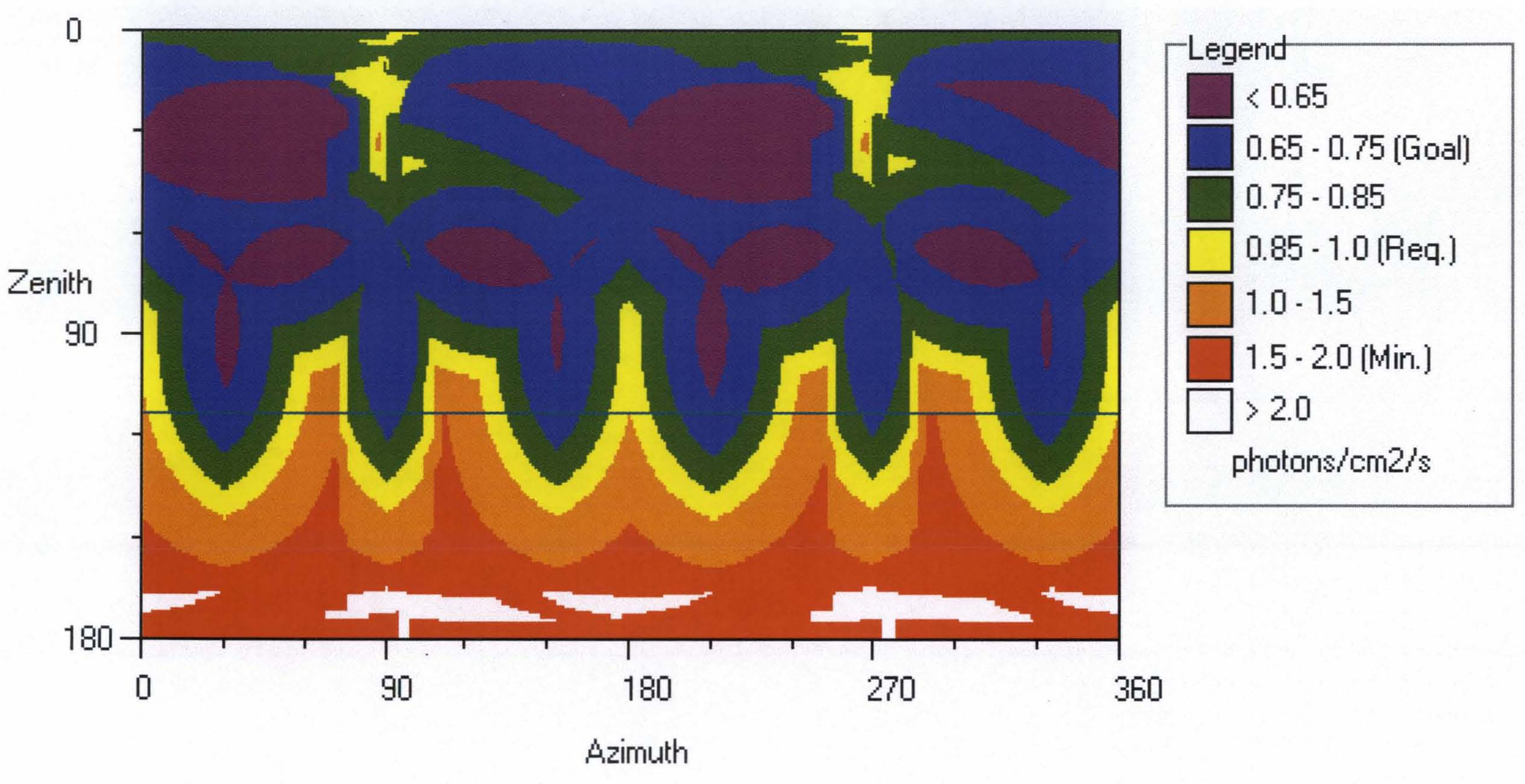
GBM flight software will implement an on-board burst trigger that will initiate an increase in data transmission. A trigger occurs if the count rates in two or more of the NaI detectors exceeds a specified statistical significance above the background rate. The required significance is separately adjustable for five different time scales (16 ms, 64 ms, 256 ms, 1.024 s, and 4.096 s) in up to five adjustable energy ranges.

When a burst trigger occurs, GBM begins transmitting time-tagged event data for 300 seconds. A ring buffer of 500,00 pre-trigger time-tagged events is also transmitted. On-board software also computes the direction to the event, the classification likelihood (GRB, solar flare, particle precipitation, etc.), and peak flux and fluence estimates. These parameters are sent to the LAT and to the ground in near-real time. Trigger information will be distributed to ground-based observers via the GCN.

The predicted rate of GRB triggers is 200 per year. The total data rate will depend on the trigger rate but is expected to be approximately 1.3 Gigabits per day

Trigger Threshold

This plot shows the on-board trigger threshold as a function of spacecraft coordinates, as determined by a simulation of the detector response and blockage by the LAT and the spacecraft. This assumes a trigger energy interval of 50 – 300 keV, 1.024 s integration time, and 4.5σ above background. The horizontal line at a zenith angle of 113° represents the earth's horizon when the spacecraft is zenith pointing.

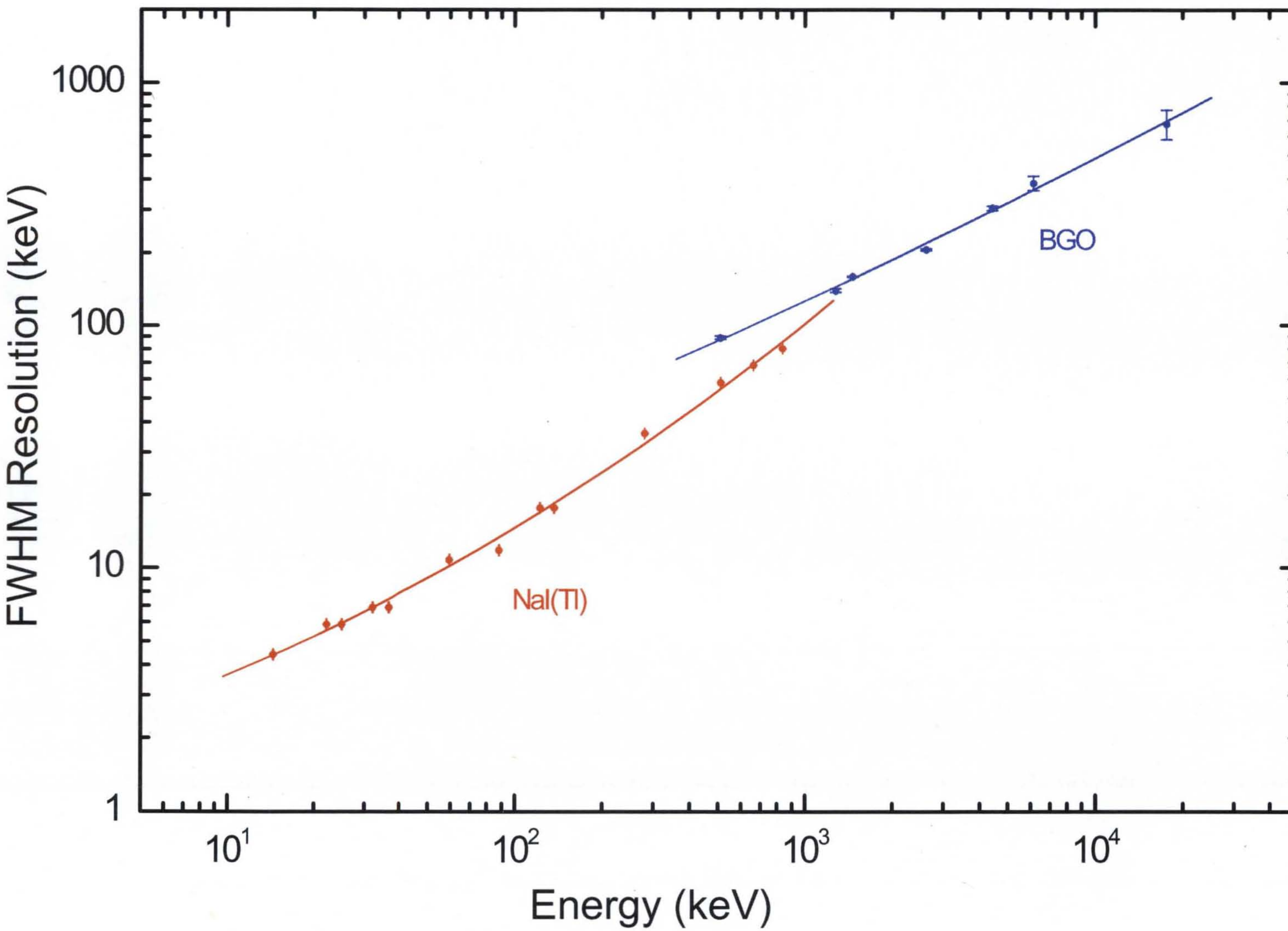


Data Types

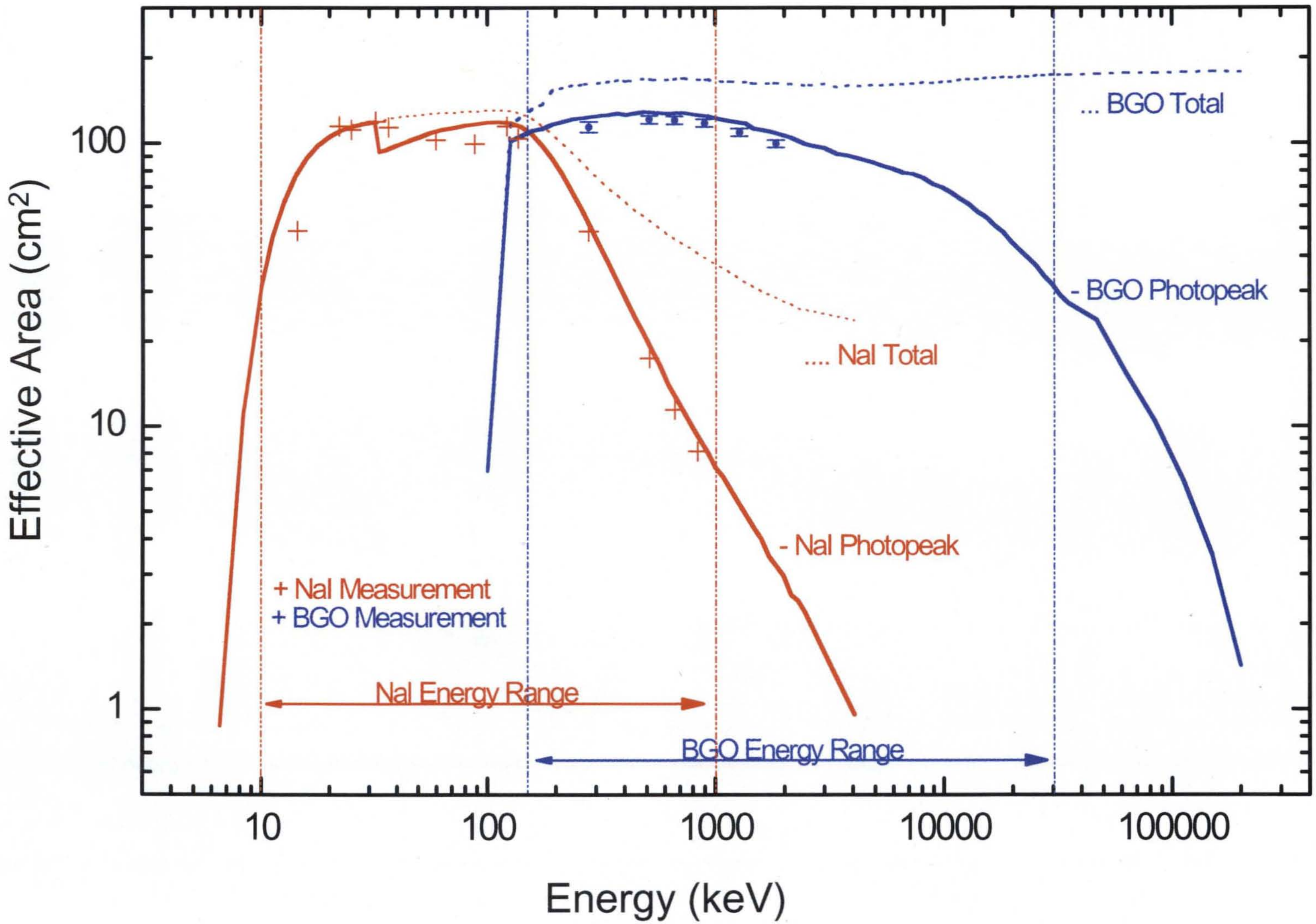
GBM will at all times transmit two types of histograms of spectra from each of the detectors. The CTIME data type emphasizes temporal resolution, while the CSPEC data type emphasizes spectral resolution. The temporal resolution and energy channel boundaries of both CTIME and CSPEC are under software control. Time-tagged event data are transmitted for a limited time during bursts. The following table summarizes the nominal characteristics of the data types.

Name	Purpose	Temporal Resolution	Spectral resolution
CSPEC	Continuous high spectral resolution	Nominal: 8.192 seconds During Bursts: 2.048 seconds Adjustable Range: 1.024 – 32.768 s	128 energy channels (adjustable channel boundaries)
CTIME	Continuous high time resolution	Nominal: 0.256 seconds During Bursts: 0.064 seconds Adjustable Range: 0.064 – 1.024 s	8 energy channels (adjustable channel boundaries)
TTE	Time-tagged events during bursts	2 microsecond time tags for 300 s after trigger; 500K events before trigger.	128 energy channels (adjustable channel boundaries)

Energy Resolution



Detector Effective Area



System Performance

Parameter	Expected or Measured Performance
Energy range	~8 keV – 30 MeV (measured)
Energy resolution	15% FWHM at 0.1 MeV (measured) 8% FWHM at 1.0 MeV (measured)
On-board GRB locations	<15° for any pointing; <8° for S/C zenith angle <60°
GRB sensitivity (5 σ, on ground)	0.47 photons cm^{-2} s^{-1} (peak flux, 1 s, 50–300 keV)
GRB on-board trigger sensitivity	0.71 photons cm^{-2} s^{-1} (peak flux, 1 s, 50–300 keV)
Field of view	9.0 steradians